

# An outbreak of cancer and asbestosis among former amosite-exposed subjects in Ledro Valley, Italy. From discovery to environmental cleanup

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## Abstract

Here are reviewed the studies conducted on asbestos-amosite pollution and its effects on the health of workers exposed from 1928 to 1973 at the Collotta-Cis factory of Ledro, Italy. The methods adopted to conduct the initial research, involving the population itself and the local administrations are described. The data summarized include: epidemiological studies of mortality carried out in 1977-85 and updated in 2009; results of the investigations carried out throughout the 1980s on the health consequences on workers, their families and residents near the factory; process of environmental cleanup from asbestos of the industrial area, completed in 1989, and the pollution risk assessment in the whole Ledro Valley. Although this was a small community of about 400 workers, these studies show that exposure to asbestos is responsible for the death of 81 people (22 mesotheliomas, 21 asbestosis, 38 malignant tumors of the lung, digestive system, ovary), for 1400 years of life lost, and for about 100 invalidity pensions, as recognized to former workers by INAIL.

## Key words

- asbestos-amosite
- cancer
- mesothelioma
- environmental cleanup
- population involvement

## INTRODUCTION

Since 1900 the factory Collotta-Cis of Molina di Ledro, Trentino, Northern Italy, produced various compounds containing magnesium carbonate. However, in 1928 a new line of manufacturing was started, which marked the future of the factory and of the entire Ledro Valley forever: on one hand by bringing new jobs, bread and wellbeing, but on the other by causing suffering and grief both among those who worked in direct contact with asbestos, but also among those who unconsciously inhaled the fibers for years despite never setting foot in the factory.

The new product of the manufacturing was a compound called “super-insulator”, a highly effective thermal insulator composed of a mixture of magnesium carbonate – extracted from local quarries, and amosite fibers – imported from South Africa by sea in bags of jute and transported to the Ledro Valley by truck. The final product was commercialized as slabs, smaller segments, pipe casings and a powder applicable by spray, all of which were subsequently transported to various destinations, including the ports of Monfalcone, Porto Marghera and Genoa, where the insulator was loaded on cargos and often shipped overseas.

Asbestos-containing products were manufactured at

Collotta-Cis for 45 years until 1973, when the production was interrupted due to the overwhelming competition of mineral wool as a cheaper insulating alternative.

What follows is an account of the events that occurred in that factory and valley, in the attempt of taking into account the socio-economic context while describing the manufacturing methods and workers' conditions, as well as the methods of data collection, the results of the mortality studies, the current state of health of both factory workers and non-worker exposed subjects, and what has been done to identify and eliminate the risks deriving from the persistence of asbestos inside and outside the factory.

## THE DISCOVERY

### *The first reports*

The first to realize that something was wrong, that the people in that factory were dying young “of tumors and lungs”, were the workers themselves. But in those times reporting work-related health risks could potentially be more dangerous than the risks themselves.

Ledro was a poor valley; even the land was stingy [1, 2]. Securing a job in the factory meant safety for entire families, it meant bringing bread on the table, getting out of poverty: the only alternative was the emigrant's

suitcase. Everyone held on tight to his or her job. A daily reminder of its importance were the two lines of people in front of the factory: of those at the gates looking for work, and of those leaving the valley to seek their fortune elsewhere. Losing a job in the factory was a risk that nobody could run, not even those who wanted to ask for safer working conditions.

At the time, the knowledge about asbestos was very limited, even among doctors: it was known as a health threat in the universities, but much less in peripheral hospitals [3, 4]. Yet, it was in these local hospitals that Collotta-Cis workers were hospitalized, starting as early as in the 1960s and 70s. By then, the Anti-Tuberculosis Dispensary (DAT) already had in archive several chest X-rays with diagnosis of asbestosis; the National Institute for Insurance against Accidents at Work (INAIL) had already recognized a few cases of asbestosis; the first few deaths from asbestosis, mesotheliomas and various other malignant tumors were starting to alarm the workers and their relatives. Nevertheless, it wasn't before 1977 – when the works with asbestos had already been suspended – that it was possible to start digging up the dirt.

It was in that year that the local Public Service of Occupational Medicine was founded, and the author of this manuscript started receiving the first few reports from factory workers and hospital doctors from the area.

### ***Data collection with the participation of the population and administrators***

The first mortality investigation thus started in 1977 with a painstaking yet swift work of identification of a first group of factory workers [5]. It began with meetings with the mayor of Molina di Ledro, Agnese Rosa, who became a valuable ally ever since, and continued in the home of a retired town-hall clerk, Candido Zendri, who provided a first list of workers that he had compiled – safe in the knowledge that our office would have reached out to him, sooner or later. The investigation was continued together with the population of the town and the entire valley, reaching out to former workers and relatives of the deceased, to the Office of Vital Records and the Church records for death certificates, and to the hospitals for medical records.

In the following years all the exposed subjects were finally identified through the most varied sources: interviews with co-workers of former employees who had emigrated or died, town-hall clerks and employment officers, but also through the Industrial Sickness Fund, trade unions, the Anti-Tuberculosis Dispensary (DAT), the National Agency for Prevention of Injuries (ENPI) and local hospitals [6, 7].

Data were collected for each of the 429 workers who worked at Collotta-Cis from 1928 to 1973: on one hand on their personal records, including residence, contacts of relatives, cause of death and clinical documentation (hospital health records, histological examinations) for the deceased, and health condition for the living; on the other hand related to the work they performed in the factory, including years spent working, in which departments and performing what tasks, on their level of ex-

posure to asbestos and habit of tobacco smoking, along with other general working conditions in the factory: division of work, type of asbestos used, pollution levels in the different departments [7, 8].

The area of the factory was mapped to identify the asbestos still present, while the levels of pollution were investigated in the homes of the workers and the general population [7, 8].

The collection of these data was facilitated by: 1) the geo-morphological isolation of the Ledro Valley – not easily accessible from the nearby valleys; 2) the fact that all the workers had lived within one of the 6 municipalities of the valley, altogether amounting to less than 5000 inhabitants; and 3) the support of the Mayor of Molina di Ledro who, with the help of several very active elderly workers, organized meetings with other former workers and the relatives of the deceased; this was a remarkable collective effort that led to compile all the names of workers, length of their exposure and places of emigration of the many emigrants, to inform former workers of the risks they ran, to convince them to take part in the health checks, and to encourage those who were intimidated. This body of information was collected also via questionnaires sent to former workers and their relatives, at times even to those who had left the valley but who still wanted to provide their contribution to the reconstruction of the history of asbestos.

It was therefore an experience of great collective participation, in which the investigations by the Public Service of Occupational Medicine of Riva del Garda, Trento, enjoyed the support of experts from several institutions, including the Medical School of the University of Verona, the National Cancer Institute of Milan, the Higher Institute of Health of Rome, the Occupational Clinic of Milan, the Center for the Study and Oncological Prevention of Florence, and the Armanni Pulmonology Hospital of Arco, Trento.

The support of these institutions was also helpful to break the resistance of the powerful Asbestos Users Association [9] (informally known as the “eighth sister”, after seven companies monopolizing the oil trade in those years) and their emissaries sent to the Province of Trento to block the epidemiological research in different ways, including by telling the general public that asbestos was harmless if used well, and that there was nothing true in what that young physician was saying...

However, the impact of the research in the Ledro Valley became clear a few years later, in 1985, when we organized a national conference in Arco, Trento, titled “The Neoplastic Risk from Asbestos in the Workplace and in the Living Environment”. Close to 200 scholars attended the meeting, in which the results of the Collotta-Cis studies were presented and published in the official proceedings [7], and the asbestos issue was finally discussed. It was an unprecedented opportunity to shed light on this public health issue, to encourage healthcare representatives from the rest of the country to start investigations in their own districts – if they hadn't already, and to join forces in defense of the health of both workers and the general population, similarly to how it was happening in the Ledro Valley.

These were challenging times not only for the work-

ers, but also for Occupational Health physicians, who were the first to go on trial for reporting the deaths at the workplace – sometimes even before the factory owners themselves. Indeed, this is what happened with Collotta-Cis: the author of this manuscript, as principal investigator in the studies, was the sole person to be ever summoned by the Courts of both Trento and Rovereto, Italy, upon charges of defamation. Both proceedings, however, were dismissed in the preliminary phase.

### **Exposure to asbestos**

The only type of asbestos ever worked at Collotta-Cis was amosite; this was first reported by the factory owners and workers, and then confirmed by all the analysis performed in the 1980s by the National Institute of Health in Rome, the Provincial Chemical Laboratory of Trento, and the Pavia Clinical Labor Foundation [3, 8].

No evidence suggests that the levels of asbestos' dust were ever measured in the work environment before then. Asbestos-amosite fibers were heavily dispersed and ubiquitous throughout the factory, although the concentration was different in different production departments. Intuitively, the steps of production that exposed workers to higher concentrations of fibers were those carried out in direct contact with asbestos, that is: emptying bags of the product of the fibers' preparation and crushing, manual pouring of asbestos into the filters to be mixed with magnesia, drying of the "super-insulator" product, cutting and shaping of the final product with planers, and milling of the production scraps to obtain the sprayable powder for thermal insulation. According to workers' reports, during these processes the amount of asbestos-containing dust in the air was at times so elevated it impaired visibility.

The ventilation and protection systems used by individuals or installed by the factory, if any, were inadequate and ineffective; no separations were placed between different departments, nor between the inside and outside the factory. All things considered, there is no evidence to suggest that the company ever took valid preventive measures.

For these reasons, even workers and inhabitants outside the factory were exposed to asbestos, including farmers working in surrounding fields and workers in nearby workshops, the village's shoemaker, truck drivers transporting the materials, the family members sharing their homes with the workers, and those living nearby the factory.

From the investigations emerged that on average 84 workers were employed by the factory at any given time, peaking at more than 120 in 1960/63; of these approximately 70% were men and 30% women. While women tended to work for shorter periods (average 5.7 years) compared to their male counterparts (9.7 years), they started working on average at a much younger age (18 years vs 32 years), sometimes as young as 14-15 years [7].

For each of these workers it was measured the Cumulative Exposure Index (CEI) by multiplying the years/months of work by a variable coefficient representing the level of exposure:  $\times 1.0$  for workers in the departments directly processing asbestos;  $\times 0.5$  for those in ad-

jacent departments and in general maintenance;  $\times 0.1$  for those in departments further away and in courtyards;  $\times 0.0$  for those outside the factory (woodcutters for fuel, miners for extraction of dolomite) or office clerks [7]. The average CEI so calculated was nearly identical in both sexes (3.8 in men and 3.3 in women), which means that – since women worked for shorter periods – they performed tasks with higher exposure to asbestos.

## **THE INVESTIGATIONS AND RESULTS**

### **Mortality studies**

The first mortality study, which dates back to 1977, was carried out immediately after the first few reports reached the Department of Occupational Medicine of Riva del Garda [5]. This represented a preliminary scientific confirmation to the suspicions of the factory workers, who had noticed an alarming high number of deaths by asbestosis and cancer amongst those who had worked asbestos in that factory over the previous 45 years.

During the following years, after the whole cohort of the exposed workers was identified, it became possible to calculate the cumulative exposure levels to asbestos for each individual and thus carry out a complete epidemiological study of mortality. This was initially presented at the International Symposium on Occupational Tumors of the International Labour Organization (ILO) in Helsinki in 1981 (Parolari G, Merler E, Riboli G) [10], and later at the National Convention in Arco, Trento, in 1985 (Parolari G, Merler E, Bertazzi PA, Zocchetti C, Carnevale F, Berrino F) [11]. These works confirmed a significant increase of tumors and asbestosis among Collotta-Cis former workers, and were in line with both the preliminary data on the same cohort published in 1977, and those on a different cohort of US workers also exposed to amosite published by Selikoff *et al.* [12].

The mortality study was subsequently updated in 1990, 1995 and 2009 [13-15].

As of 2009, of the 429 known workers who were employed by Collotta-Cis in the period 1928-73: 372 resulted to be exposed to asbestos (218 men, 154 women), 48 were not (woodcutters, miners, office workers), and 9 were not identified. Of the 372 workers exposed to asbestos, 281 had died in the 70 years from 1940 to 2009: 105 for cancer, 18 for asbestosis, 158 for other causes [15, 16] (Table 1).

There are a number of reasons for which there was value in keeping up to date the mortality studies on the Ledro Valley cohort. First, this is one of the few epidemiological studies in literature on workers exposed exclusively to amosite, a commercial type of asbestos of the amphibole group, the one with greatest carcinogenic power [12, 17, 18, 19]. Second, in this cohort it was identified a correlation between asbestos and tumors of the digestive system, of particular interest in the field [20, 21]. Third, it was the first cohort studied in Italy and has thus been kept under observation for 40 years. Finally, although small, the Ledro Valley's cohort includes subjects at very high exposure, a large number of women, and shows high mortality rates for several causes [3, 10, 11].

**Table 1**

Collotta-Cis: mortality study, updated to 31 December 2008. Modified from [15]

	Males	Females	Total
Workers in the study	218	154	372
Living	24	67	91 (24.5%)
Deceased from 1940-2008	194	87	281 (75.5%)
Died for cancer	73	32	105
<i>Respiratory system (excluding pleural mesothelioma)</i>	19	2	21
<i>GI tract (excluding peritoneal mesothelioma)</i>	36	5	41
<i>Pleural mesothelioma</i>	3	7	10
<i>Peritoneal mesothelioma</i>	1	2	3
<i>Ovarian tumors</i>		3	3
<i>Tumors in other sites</i>	14	13	27
Deceased due to asbestosis (not complicated by cancer)	13	5	18
Died for other causes	108	50	158
<i>Cardio-vascular diseases</i>	63	32	95
<i>Respiratory diseases (excluding asbestosis)</i>	20	9	29
<i>GI tract diseases</i>	8	2	10
<i>Traumas</i>	6	0	6
<i>Other causes</i>	11	7	18

During the 1980s, it was analyzed the mortality for cancer among the Ledro Valley inhabitants who had never worked at Collotta-Cis, which showed no difference when compared to that population of Arco, Trento, a neighboring but non-exposed area [22]. However, within the valley, an unusual number of mesothelioma cases were described among family members of Collotta-Cis workers, residents near the factory, and external workers exposed to the factory's asbestos.

#### **Epidemic of tumors and asbestosis among workers, dose-effect relation**

These epidemiological studies showed that exposure to asbestos-amosite increased mortality of Collotta-Cis workers, both among those directly involved in processing the "super-insulator" and those indirectly exposed to asbestos.

In the comprehensive 1985 study, the mortality of Collotta-Cis workers was compared to that of Italy and of the neighboring city of Trento – matched by gender, age and time period [11].

The Standardized Mortality Ratios (SMR) so obtained showed a significant increase of incidence for all tumors (SMR 1.93, 95% Confidence Interval (CI) 1.37-2.65 in comparison with the Italian population) (SMR 2.00; 95% CI 1.45-2.71 in comparison with the population of Trento), for tumors of the digestive system (SMR 2.44; 95% CI 1.51-3.73 – Italy) (SMR 2.03; 95% CI 1.25-3.10 – Trento), and for lung tumors (SMR 2.38; 95% CI 1.14-4.38 – Italy) (SMR 1.70; 95% CI 0.81-3.63 – Trento).

For tumors of the digestive system, the measured risk was also several times higher, especially for esophageal (SMR 8.47; 95% CI 2.71-19.44 – Italy) (SMR 5.25; 95% CI 1.71-12.26 – Trento) and rectal tumors (SMR

5.84; 95% CI 1.56-14.63 – Italy) (SMR 4.71; 95% CI 1.28-12.05 – Trento) [11] (Table 2).

For pulmonary tumors, mortality rates increased with cumulative exposure to asbestos and with tobacco smoking, although the number of tumors was significantly increased only for latencies greater than 20 years from the initial exposure [11].

Mortality due to non-neoplastic respiratory causes was also high, statistically significant and correlated to the exposure levels.

As of the 2009 study updates [15, 16], 39.9% of deaths among the exposed Collotta-Cis workers (105/263) were caused by cancer (excluding those from asbestosis) – 40.3% (73/181) in men and 39.0% (32/82) in women. This number was even higher when considering only the most recent period (1991-2008), accounting for to 43.8% of deaths (39/89) –46.8% (22/47) in men and 40.5% (17/42) in women (Table 3).

At the same time-point, 18 deaths were attributable to asbestosis; this is likely an underestimation for two reasons: 1) before 1980 this disease was underdiagnosed and rarely reported; 2) when deaths were caused by both cancer and asbestosis, they were reported as caused by cancer alone.

In addition to the overall increase, it was observed a clear dose-effect relation between exposure to asbestos-amosite and mortality: the Standardized Mortality Ratio (SMR) directly increased as a function of the duration of exposure alone, but increased even more when both duration and intensity of exposure were combined as Cumulative Exposure Index (CEI). In particular, for high cumulative exposure (CEI > 6) the SMR for all tumors in males (SMR 2.59; 95% CI 1.42-4.35 – compared to the Italian standard population) was higher than in the medium – (CEI 2-6: SMR 2.22; 95% CI



**Table 2**

Collotta-Cis: standardized mortality ratio (SMR) and 95% confidence intervals (95% CI) as compared with the population of Italy and of the city of Trento, 1985 [11]

Pathology code		Standard: Italy	Standard: City of Trento
		SMR (95% CI)	SMR (95% CI)
140-209	All tumors	1.93 (1.37-2.65)	2.00 (1.45-2.71)
150-159	Tumors of the GI tract	2.44 (1.51-3.73)	2.03 (1.25-3.10)
150	Tumors of the esophagus	8.47 (2.71-19.44)	5.25 (1.71-12.26)
154	Tumors of the rectum	5.84 (1.56-14.63)	4.71 (1.28-12.05)
162	Tumors of the lungs	2.38 (1.14-4.38)	1.70 (0.81-3.63)
200-209	Tumors of the blood	2.61 (0.52-7.31)	2.55 (0.53-7.46)

**Table 3**

Collotta-Cis: frequency of deaths due to cancer, 2009. Modified from [15]

Date of death	Males	Females	Total
< 1975	28/77 (36.4%)	6/18 (33.3%)	34/95 (35.8%)
1976-90	23/57 (40.4%)	9/22 (40.9%)	32/79 (40.5%)
1991-2008	22/47 (46.8%)	17/42 (40.5%)	39/89 (43.8%)
Total (1940-2008)	73/181 (40.3%)	32/82 (39.0%)	105/263 (39.9%)

1.07-4.09) and lower-exposure groups (CEI < 2: SMR 1.44; 95% CI 0.79-2.42). A similar observation was made for tumors of the digestive system (CEI > 6: SMR 3.75; 2-6: SMR 2.63; < 2: SMR 1.63), for lung tumors (> 6: SMR 2.73; 2-6: SMR 3.64; < 2: SMR 1.50) and for non-neoplastic respiratory diseases (> 6: SMR 2.50; 2-6: SMR 1.76; < 2: SMR 1.40) [11].

As of the 2009 study updates, 52.1% (25/48) of workers had died of tumor in the high cumulative exposure group (> 6), 39.4% (41/104) in the medium- (2-6) and 35.1% (39/111) in the low-exposure groups (< 2). As expected, no increase in mortality due to tumors was observed in the group of non-exposed workers (woodcutters, miners, office employees; 18.9%; 7/37) compared to controls. No significant differences between genders were observed [15, 16].

If we consider the combined mortality from cancer and asbestosis, the correlation between exposure and mortality is even more striking: 17 of the 20 (85%) most exposed Collotta-Cis workers died of cancer and/or asbestosis – 9 of cancer, 6 of asbestosis, 2 of asbestosis complicated by cancer; of the 11 tumors: 3 were mesotheliomas, 3 lungs, 4 GI system, 1 ovary [15, 16].

### ***Mesotheliomas, deaths attributable to asbestos, and years of life lost***

If asbestos had never been processed in the Ledro Valley, based on the standard Italian incidence, there shouldn't have been any case of mesothelioma among the 400 Collotta-Cis workers and their families (expected cases: 0.21) [23, 24, 25]; instead, 22 people died of

mesothelioma (17 of the pleura, 5 of the peritoneum) in those years: 4 before 1985, and 6 in each of the following decades (1986-95, 1996-2005, 2006-15).

Of these 22 cases, 16 were former Collotta-Cis workers (including 1 driver) and 6 were indirectly exposed (4 relatives of workers, 1 environmental, 1 professional outside the factory). Among the non-factory workers was the shoemaker of Molina di Ledro, who was exposed to the asbestos fibers while repairing the worker's shoes and sewing the factory's jute bags; a woman who had lived in her youth near the factory; 4 family members (2 wives, a daughter and a sister) of 4 different Collotta-Cis workers who inhaled asbestos while brushing their relatives' work clothes, cleaning their shoes, sleeping on the pillow where the husband had laid his contaminated hair. The strong emigration from the valley in the years made it often complicated to identify these victims, to confirm if they were alive or dead, and if so to attest their cause of death. However, for these 22 cases of mesothelioma, it was possible to confirm the diagnosis as certain (histological confirmation available) in 15 instances, as probable in 1 (cytological confirmation available) and as possible in 6 (radiological, clinical, death certification) [3, 16].

While the small numbers of this cohort advise against drawing hard conclusions, it is interesting to highlight a trend suggesting an inverse correlation between cumulative exposure levels and average latency of mesotheliomas, which was shorter in the group at high-exposure (41 years) when compared to all other groups (averaging 50-52 years) – whether directly or indirectly

exposed. As of 2015, the incidence of mesotheliomas among the Collotta-Cis workers was 0% (0/57) for subjects with latency up to 25 years, 5.6% (4/72) in those with latency 26-40 years, 7.3% (6/82) for latency 41-55 years, 8.7% (6/69) for 56-70 years, and 0% (0/15) over 70 years. It will be useful to monitor over time the approximately 50 former workers still alive, who have by now reached on average almost 60 years from the beginning of the exposure [3, 26].

It is also worth noting that mesotheliomas affected more the ex workers (mainly women, 11 out of 16) who started to be exposed to asbestos at an early age. In fact, of the 16 cases of mesothelioma, 6 occurred in workers who began their exposure at 15 or younger (6/48), 6 between the ages 16-19 (6/55), and 4 between 20-30 (4/74); no case of mesothelioma occurred among the 138 workers deceased by 2015 (123 men and 15 women) who started to be exposed to asbestos when older than 30yo. The same observation applies to the cases of mesotheliomas among non-factory workers: they affected predominantly women (5/6) who started exposure at a young age. The period of latency of the disease was on average 49 years, ranging between 29-68 [3, 15, 16].

As for cancer cases, if the cohort of Collotta-Cis workers exposed to asbestos died with the same frequency of the control populations (Italian and remaining population of Ledro Valley), only 54 should have been deceased by 2009; however, the deaths for cancer were 105 in this group, which suggests that these 51 tumors in excess are attributable to asbestos exposure. Adding them to the 18 deaths due to asbestosis, 69 former Collotta-Cis workers died as a result of exposure to asbestos, that is one in four of the 281 dead workers. With the addition of the 6 mesotheliomas among the exposed non-workers, the death count goes to 75 [15, 16]. As of today, 3 more deaths for mesothelioma and 3 for asbestosis have been described, bringing to 81 the number of people who lost their lives in the Ledro Valley due to the work with asbestos at Collotta-Cis factory [3].

Finally, we compared the life expectancy at 40 years of age of the exposed workers with that of the rest of the Ledro Valley population (until 1990) and of the overall Italian population (after 1990): by 2009, Collotta-Cis workers lost a total of 1382 years of life, that is they lived on average 5.2 years less [15, 16]. With the addition of the years of life lost due to the cases of mesothelioma in the non-factory workers, the count exceeds 1400 years.

#### ***Health status of living workers, surveys on residents, occupational disability pensions***

During the early 1980s, 167 former Collotta-Cis employees (of the 248 then alive) were subjected to health checks: medical examination, chest X-ray, spirometry, measurement of the diffusing capacity of the lung for carbon monoxide (DLCO), and research of corpuscles of asbestos and siderocytes in the sputum. Of the 87 new cases of asbestosis diagnosed (52.1% of former workers visited), 56 (33.5%) were cases of pleural plaques, 17 (10.2%) of pulmonary asbestosis and 14 (8.4%) of the two joint diseases [27, 28, 29].

From the chest X-rays emerged a correlation between the intensity of exposure to asbestos (both in years of exposure and CEI) and the frequency of pulmonary asbestosis and/or pleural plaques. The habit of smoking tobacco clearly reduced the threshold-dose necessary to induce asbestosis, as well as the latency time for it to radiate. These health checks were an excellent opportunity also to make known to all workers the particularly negative effects of tobacco smoking on subjects previously exposed to asbestos, and thus reduce that unnecessary additional risk factor. In almost 40% of the 36 workers who had previous X-rays available, it was also shown a trend for pleural plaques to increase in volume and to calcify, even 30-40-50 years after the beginning of exposure [27].

With the Pulmonary Function Tests it was highlighted a strong correlation between reduction of the Vital Capacity and increase of the CEI, increase of the latency period, and presence of X-ray alterations. The measure of Vital Capacity interestingly proved to be even more sensitive than the diffusing capacity of the lung for carbon monoxide (DLCO). Additionally, tobacco smoking showed to be remarkably effective in accentuating signs of obstructive disease. Finally, the presence of asbestos corpuscles in the sputum revealed to be a good indicator of exposure to amosite, even several decades from the last exposure [30].

The health checks also involved 33 people who had lived for years nearby the factory. Among these, we identified 5 cases of pleural plaques, 2 of suspected pulmonary asbestosis (ILO Profusion Score 0/1), but none of certain pulmonary asbestosis; however, 3 cases of asbestos-induced pleural plaques had already been diagnosed a few years prior by the local Anti-Tuberculosis Dispensary on 2 farmers and 1 mechanic who had worked near the factory [27].

All these studies were presented at the Arco Convention in 1985 [27, 30].

Asbestosis and tumors of suspected occupational origin have been thereafter reported to INAIL, which allocated about 100 disability pensions for work-related illnesses, reparations that gave back some degree of justice to workers and their families. Among these reimbursements were those to workers exposed before 1934 (before the rules on insurance against occupational diseases entered into force), thanks to a law approved by the region of Trentino-Alto Adige, with which the region entrusted to INAIL the management of those practices and provided the financial backing [15, 16, 31].

#### **ENVIRONMENTAL CLEANUP**

##### ***Mapping of asbestos pollution inside and outside the factory***

Even after its closure in 1979, the light fibers of amosite were raised in the air at any gust of wind and transported from the factory area and from the polluted structures still present. This represented a constant danger not only for those who entered the industrial area, but also for those who lived or worked nearby, and for those who passed on the nearby road connecting the Ledro Valley and Lake Garda.

The necessity to decontaminate the polluted area became clear, and thus the first risk mapping was carried out in 1981 by collecting samples both inside the factory and in the courtyards. The analysis showed the presence of asbestos fibers in more than 30 of the sampled locations, in high levels in the areas previously used for processing the insulating material and in moderate quantities even in the departments used to produce magnesium. The map obtained was used as a starting point for the subsequent cleanup operations [7, 8, 32].

In the same year, an investigation was also started in the homes of inhabitants of the valley to assess the diffusion of asbestos as insulating material, production waste or other polluted materials. After interviewing 143 among former factory workers, inhabitants and artisans, it turned out that the use of this insulating material in the valley was only sporadic for a number of reasons: it was not customary to use insulating materials at all, its cost was high, its removal from the factory too risky, and the production waste – made of a mix of magnesium and asbestos – was all milled at the factory to be sold as powder for industrial or civil spray applications.

Jute sacks instead, which had contained asbestos and were still heavily contaminated, had been widely used in the valley as containers for potatoes or hay, and as work aprons [8, 32].

#### ***Environmental cleanup of the industrial area and surroundings***

The first cleanup operations involved the most polluted areas of the factory and were carried out by the Municipality of Molina di Ledro in 1981-82. Lacking any regulation on the matter, the city performed them swiftly following the few recommendations then available, and with the collaboration of the factory workers themselves. These workers, who until a few years earlier had handled asbestos without much protection, found themselves puzzled to be performing those same tasks, yet this time equipped with overalls and disposable shoes, masks with adequate filters, taking showers at the end of the work. The asbestos and polluted material were removed from the factory, sealed in polyethylene bags and sent to an authorized landfill in France. These procedures reduced greatly the health risks due to the dispersion in the air, as well as any possible contact with the fibers for those who may have entered the abandoned property, out of curiosity or to play, as it often happened with the children in the area [7, 8, 32].

Meanwhile, the complete cleanup of the factory and surrounding land was being planned; this included the white mountain made of tens of thousands cubic meters of calcium carbonate, the production waste of decades of work that had been piling up in the courtyards near the factory, nearby a stream. From the geological analysis, it turned out that this build-up was sitting on an aquifer: the presence of these large volumes and unstable weights, located upstream of several towns and of Lake Garda, represented a grave health threat and influenced the decisions to further expedite the interventions.

In 1988 the full cleanup of the walls, beams, planks and roofs was carried out; the only exception were a small shed and a house located at the edge of the indus-



**Figure 1**

1988. Environmental cleanup operations of the Collotta-Cis Area (Industrial Technologies Milan).

trial area, still existing today, where asbestos had never been deposited or worked. While performing this task, Industrial Technologies of Milan used safe working methods for workers and for the neighboring residents, according to the procedures defined in the works contract, followed by regional and national recommendations and EEC Directives that had meanwhile entered into force [33-37] (Figure 1).

Once the cleanup phase was completed with the dispatch of the material to the authorized landfill, the building was razed to the ground in 1989. During the works a constant rain of water was sprayed on the structures, so as to prevent dust and fibers to lift up in the air, yet without washing them away in the aquifer and stream. The demolition waste, together with the most superficial 50 cm of soil of the surrounding land, was brought to the tunnels where decades before the dolomite was extracted to produce magnesia: the ideal shelter for that material, still potentially polluting.

The trucks, after the surface of the loaded wastes had been sprayed with a glue-containing solution, were sealed with tarps to prevent the dispersion of dust during the passage near the inhabited areas. The industrial area was thus decontaminated in conditions of maximum safety, under constant environmental monitoring, and was subsequently reconverted to industrial use.

The first Italian cleanup of an asbestos factory was thus completed in Molina di Ledro in 1989 [3, 16].

As for the jute sacks, which were still polluted with asbestos, they had already been completely discarded by the citizens as soon as they had heard of the carcinogenicity of asbestos, together with the little insulating material they used in their homes. When providing questionnaires to residents, the chance was also seized to provide further indications on how to carry out possible small procedures of cleanup in the homes while minimizing health risks [3, 32, 38].

The fact that the asbestos pollution outside the factory was modest, as assessed by the complete mapping of the Ledro Valley, was also confirmed by the lack of mesothelioma in the general population, which would have certainly been different in case of widespread pollution. The pollution from asbestos outside the factory and its harmful effects on health seem therefore to have

been limited to the Collotta-Cis workers' homes and to the areas in close proximities to the factory.

## CONCLUSIONS

The investigations on the Collotta-Cis factory of Molina di Ledro were instrumental to research and inform the public about the damages caused by asbestos fibers on the health of workers and residents, to describe what happened in the factory and outside, and to answer the many questions of workers, family members and public administrators. The final results of which are a count of 81 deaths from cancer and asbestosis caused by asbestos, 1400 years of life lost, and about 100 disabled workers recognized by INAIL. This is something really surprising, considering it all occurred in a small community of only 400 asbestos workers.

These studies confirmed the danger of asbestos-amosite, the increased incidence of mesothelioma and tumors of the lung, digestive system and ovary in those exposed, as well as a clear dose-effect relation. Of particular relevance in this cohort is the high number of tumors affecting the digestive system, also observed in other cohorts of exposed to amosite. Although the case of Ledro Valley is small, and consequently the number of mesotheliomas is limited, the studies here summarized have indicated possible trends on the incidence of mesotheliomas, including a reduction of latency in cases of high cumulative exposure, and a change in incidence with the duration of latency. Additionally, exposure to asbestos at an early age was correlated with higher incidence of mesothelioma, in particular among women, while, conversely, no cases of mesothelioma was observed among those who started exposure after 30 years of age; this interesting observation is worth further investigations.

The studies here reported have led to the cleanup of the industrial area, which during the 1980s was completely cleaned and subsequently repurposed to productive area, with positive effects on the health of residents and workers in the neighborhood, and on the local economy. The results of the first studies have also encouraged many families to put in place small cleanup projects, which immediately removed further dangers from their homes. It has been 30 years now since Ledro Valley has been free from the asbestos-amosite of Collotta-Cis.

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These studies were an opportunity to suggest former asbestos workers some hygienic behaviors to prevent further aggravation to their health (e.g., tobacco smoking). They have also brought justice to many whose only fault was having worked in that factory and who, for this reason, have gotten seriously ill, lost their lives, or lost a father, mother or child. Justice not only for being able to know what happened or was happening to them, but also for having received a disability pension. And, as we know, suffering is more tolerable if mitigated by some level of gratification, or at least by the reduction of financial concerns.

Finally, these investigations are useful to keep memories of these events alive for the next generations, so that such experiences are not forgotten, but remain integral part of our heritage, in the hope that what happened in the Ledro Valley will not occur again. Not only in our land, which in the meantime has evolved into a modern country where work with asbestos has been banned, but also for the countries where these dangerous processes are still practiced with the same procedures and in the same conditions as in Molina di Ledro 60 years ago. Countries where there are no bans, rules, attentions, checks and where, in a few years, some young occupational doctor will unfortunately have to count the dead, as it happened in Ledro Valley some 40 years ago.

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There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias the conduct and findings of this study.

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